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(54) **FABRIC TEMPERATURE ESTIMATION FOR A LAUNDRY DRYER**

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F26B 5/08	(2006.01)
F26B 3/00	(2006.01)
F26B 19/00	(2006.01)

(52) **U.S. Cl.**

USPC **34/269**; 34/327; 34/445; 34/89

(58) **Field of Classification Search**

USPC 34/132, 549, 572, 269, 327, 445, 34/89

See application file for complete search history.

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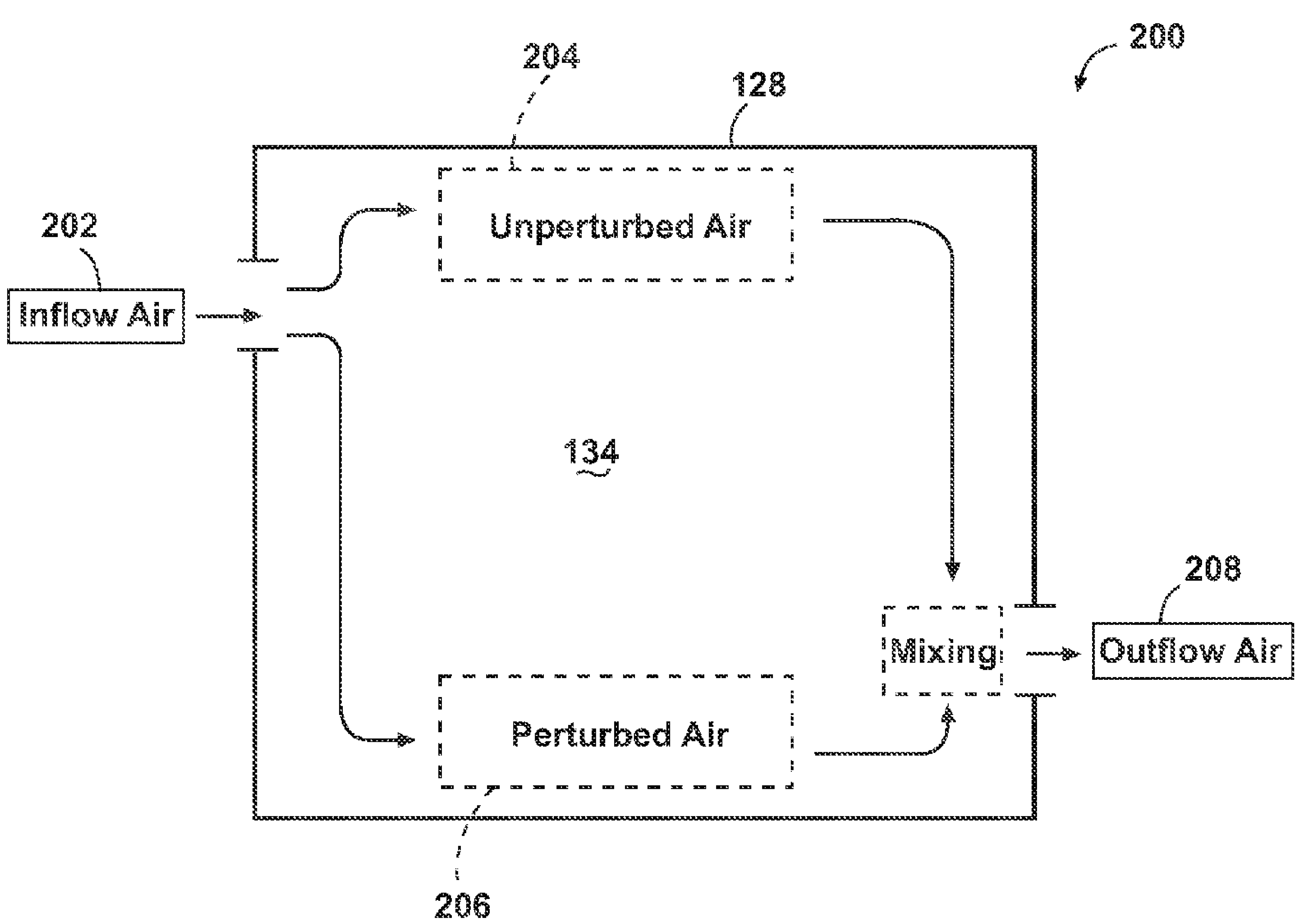
(57) **ABSTRACT**

A method for estimating the temperature of a laundry load in a treating chamber of a laundry dryer.

8 Claims, 8 Drawing Sheets



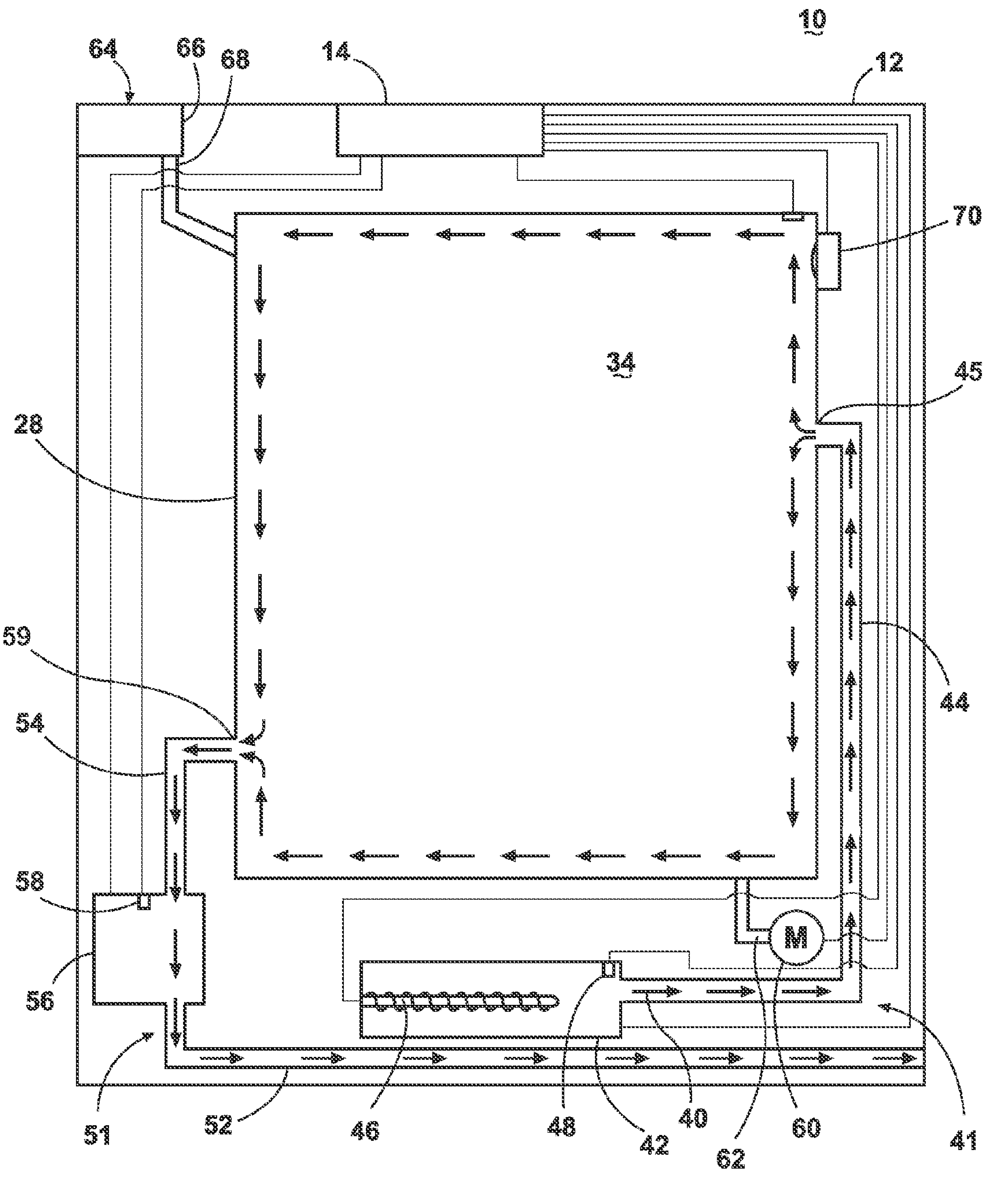


Fig. 1

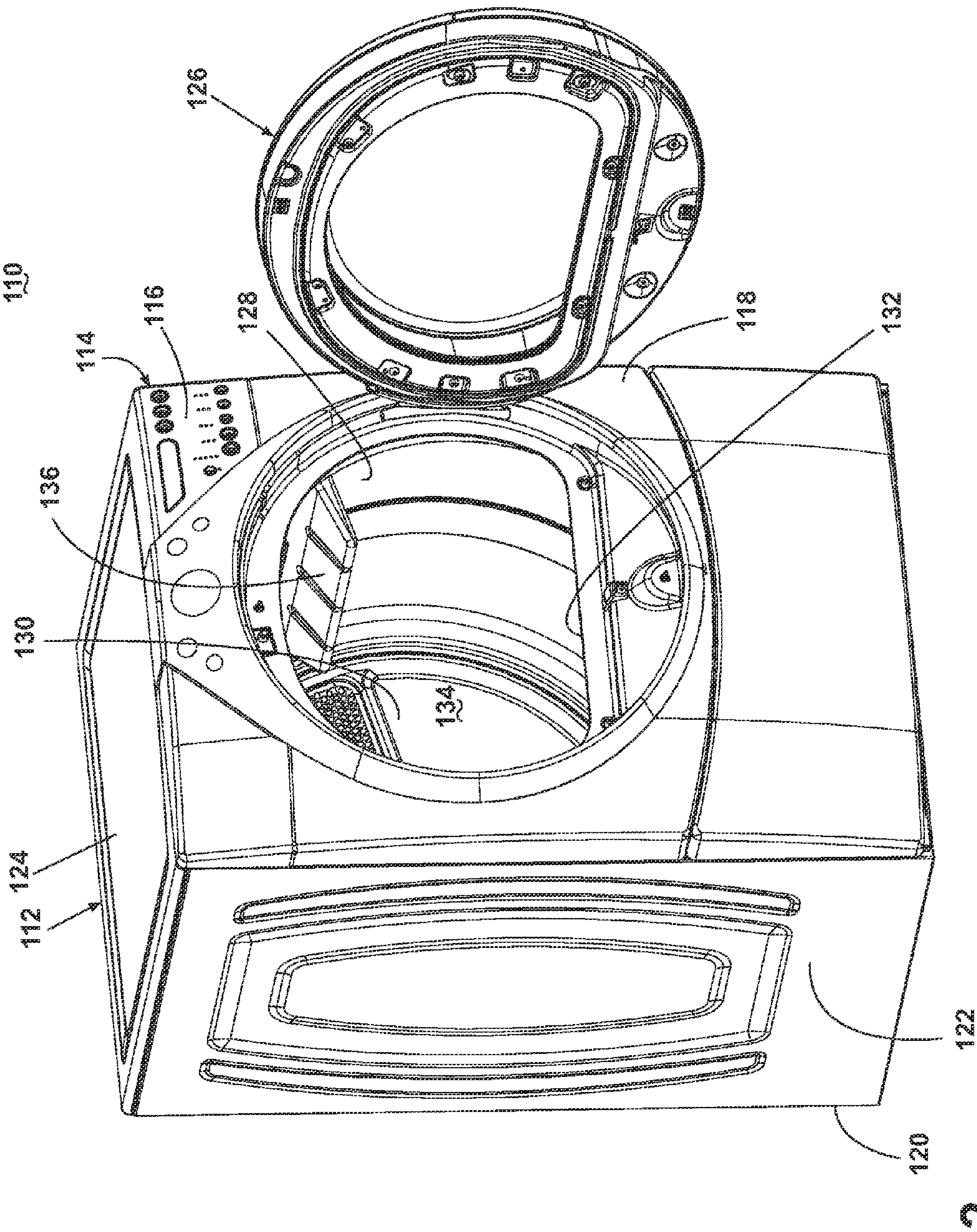


Fig. 2

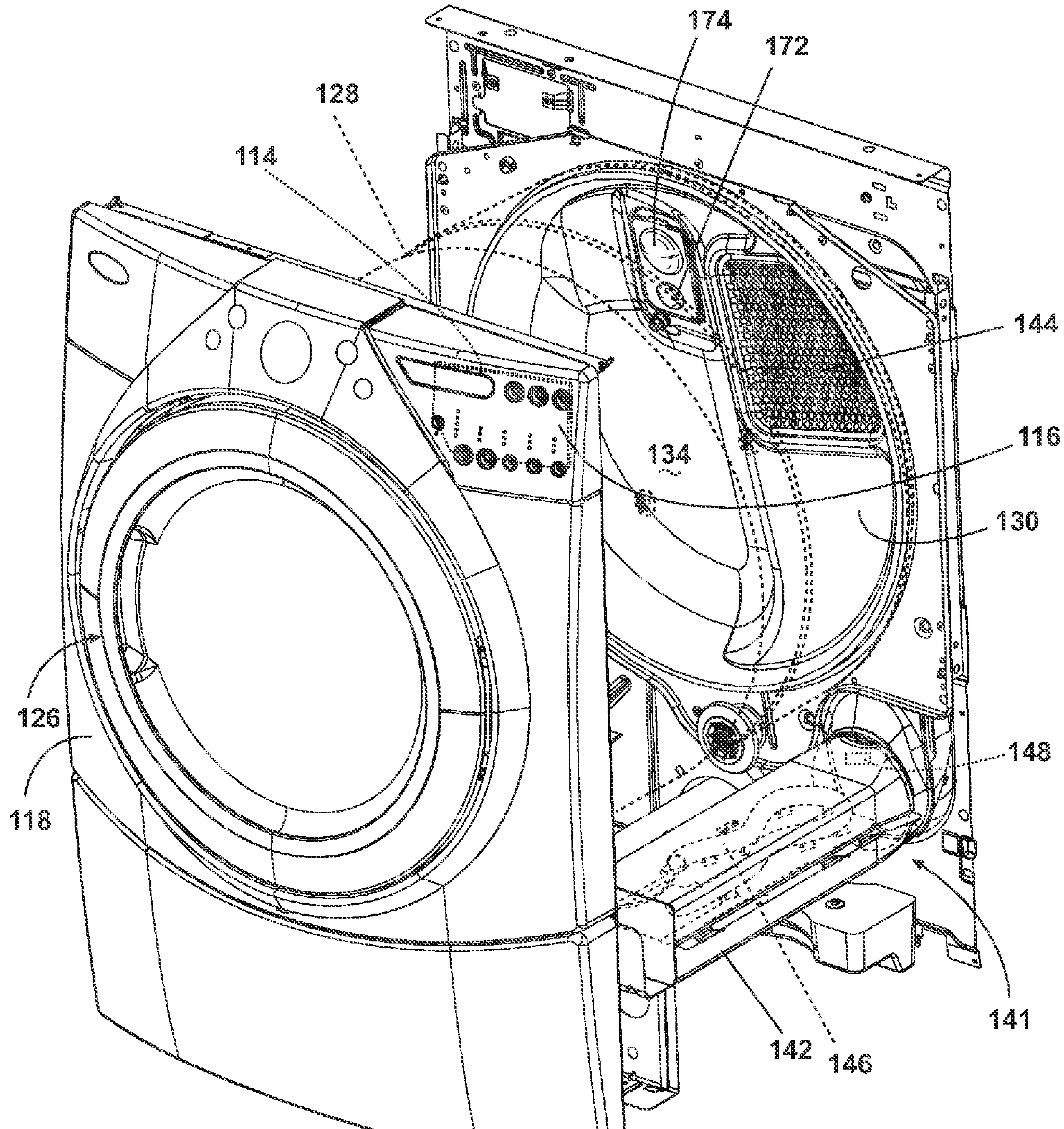


Fig. 3

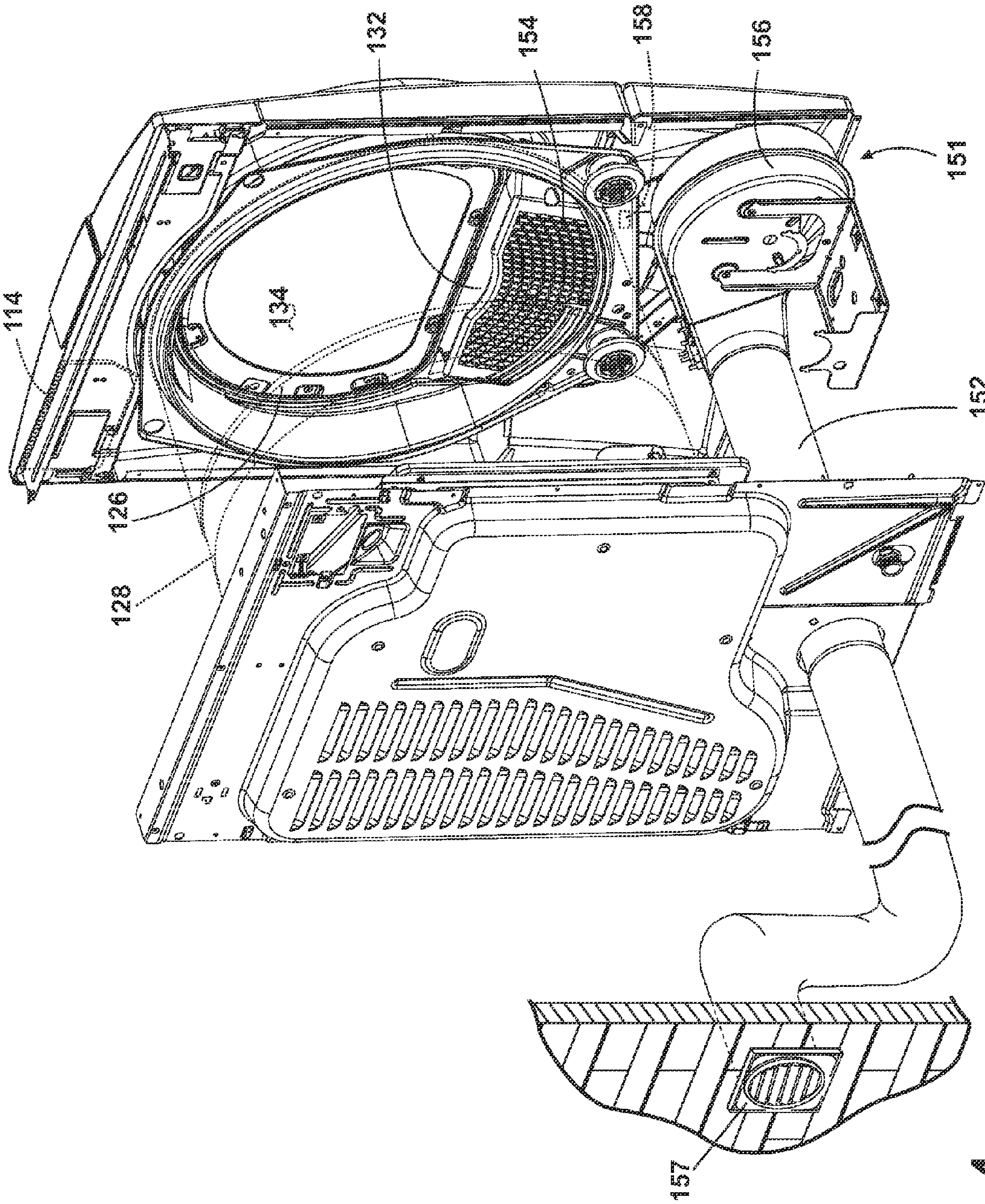


Fig. 4

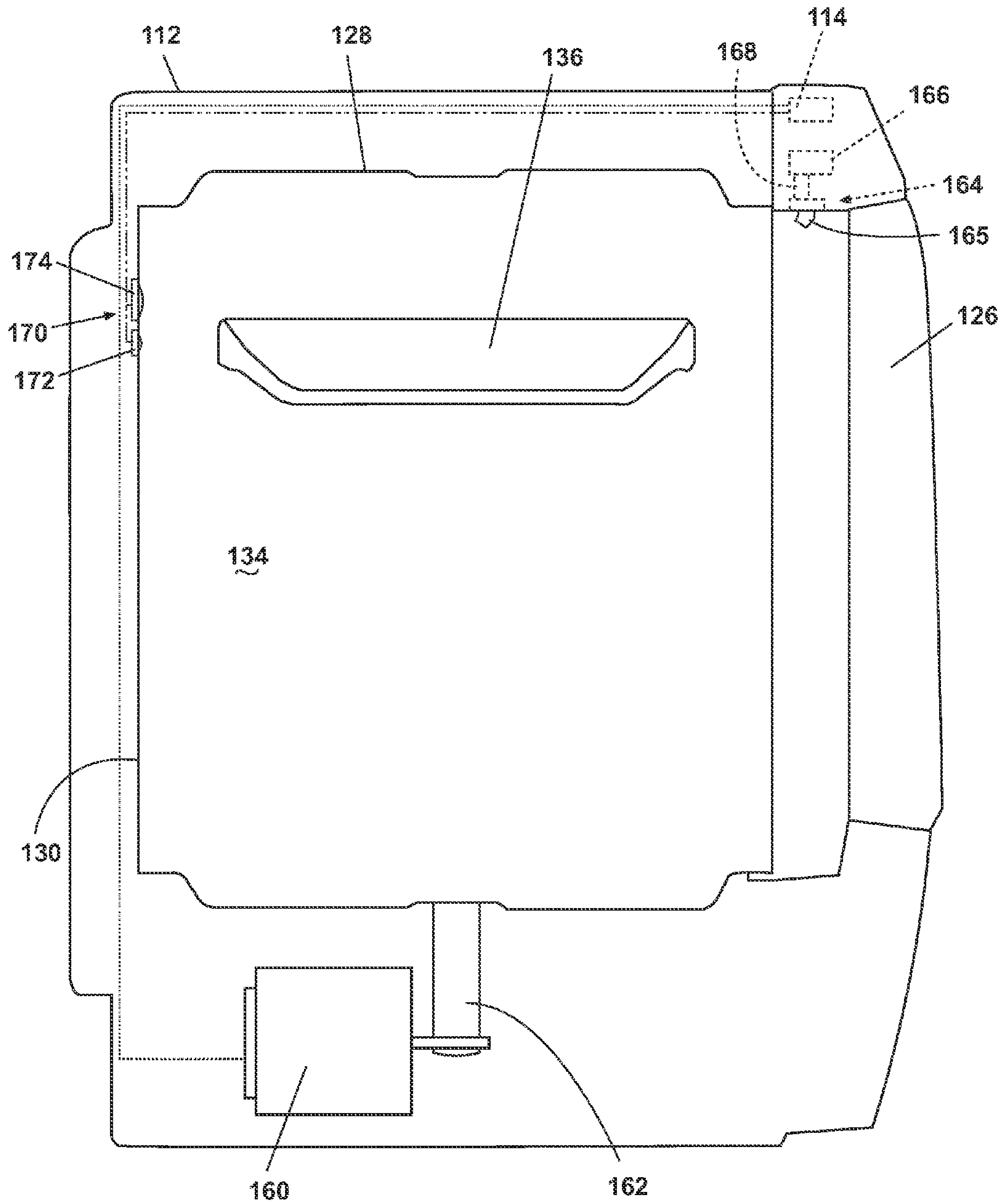


Fig. 5

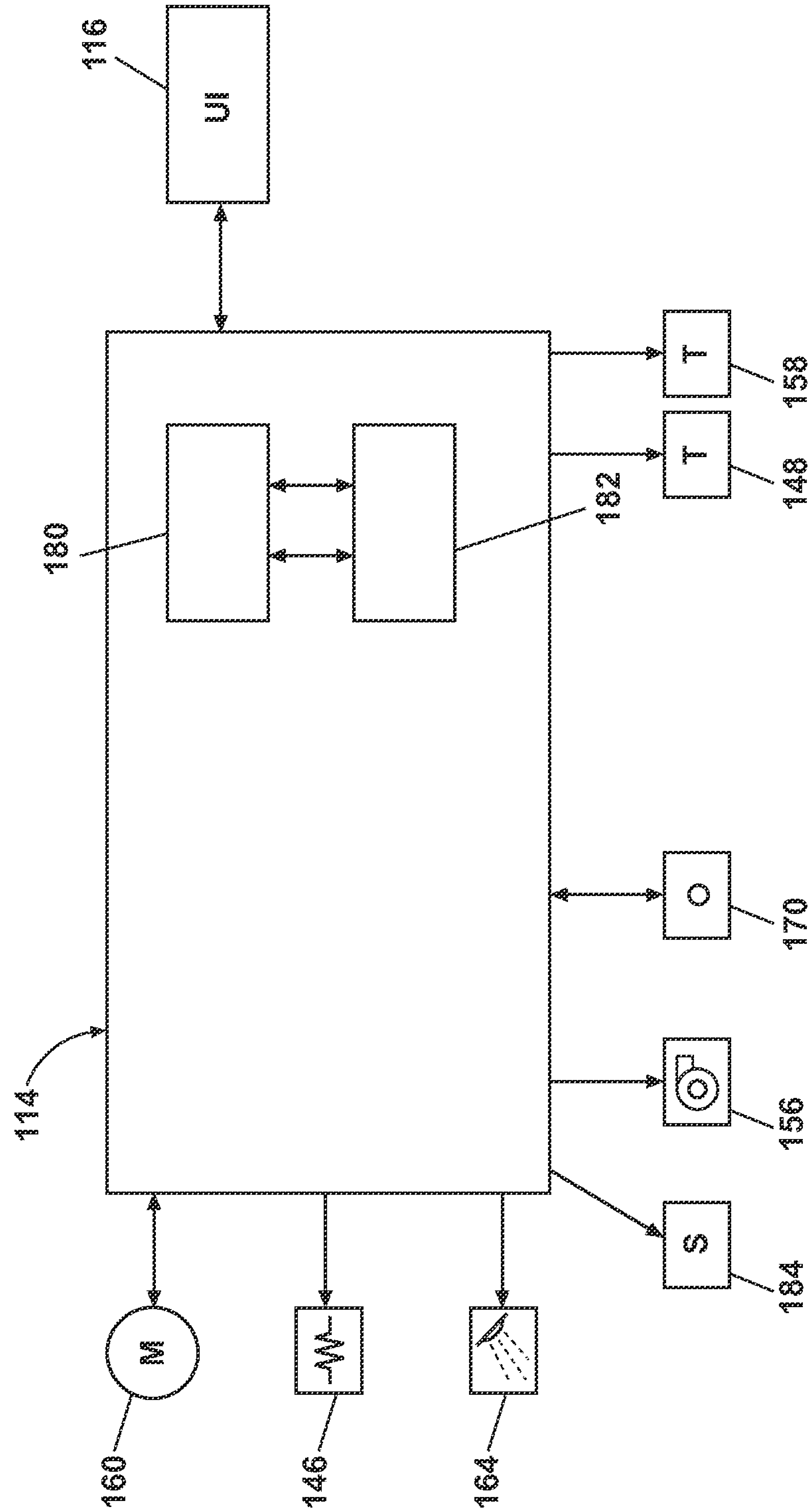


Fig. 6

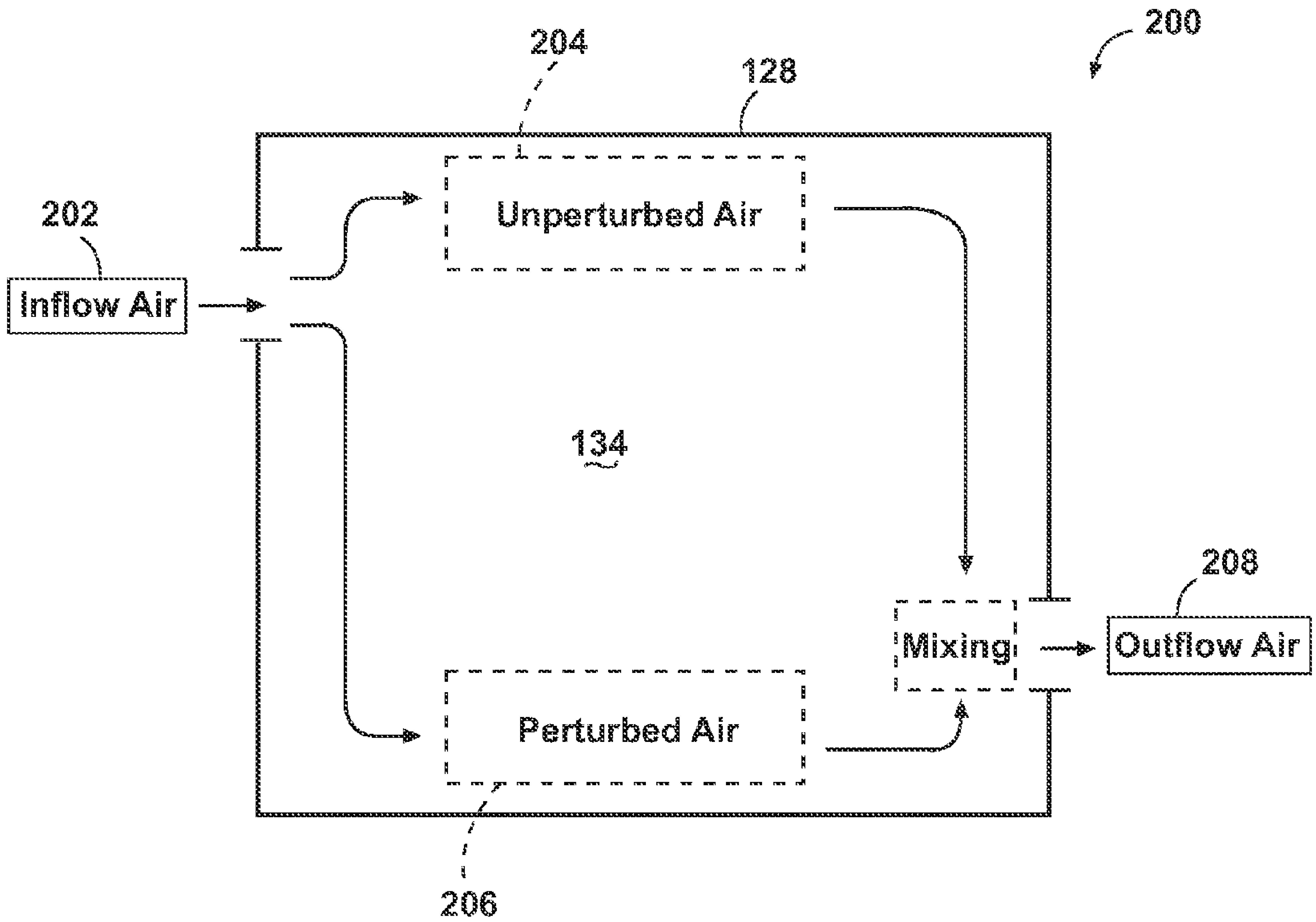

200
204
128
202
Inflow Air
Unperturbed Air
134
208
Mixing
Outflow Air
Perturbed Air
206

Fig. 7

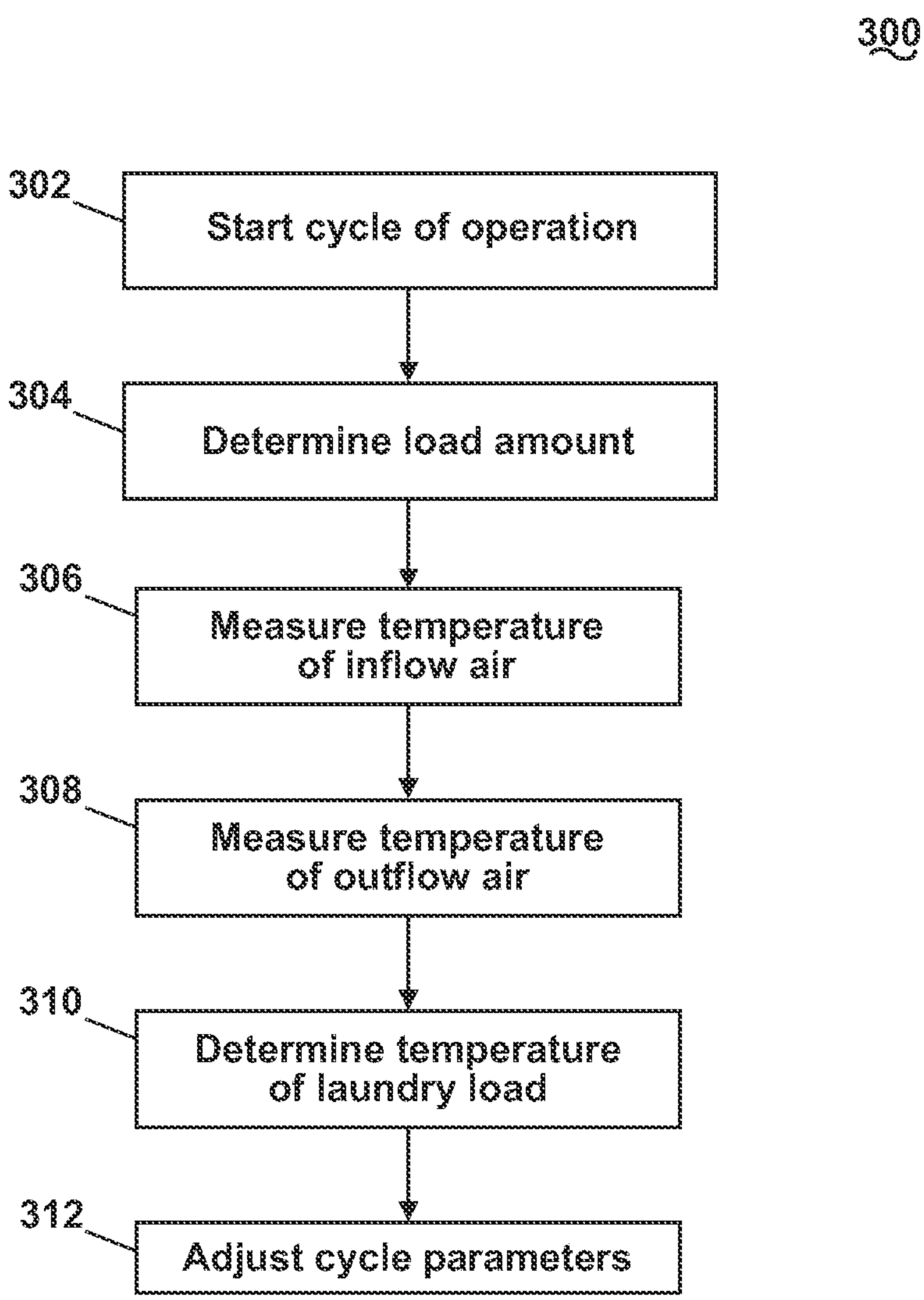

300
302
Start cycle of operation
304
Determine load amount
306
Measure temperature of inflow air
308
Measure temperature of outflow air
310
Determine temperature of laundry load
312
Adjust cycle parameters

Fig. 8

FABRIC TEMPERATURE ESTIMATION FOR A LAUNDRY DRYER

BACKGROUND OF THE INVENTION

A laundry treating appliance, such as a clothes dryer, typically has a configuration based on a rotating drum that defines a treating chamber in which laundry items are placed for treatment. The clothes dryer may have a controller that implements a number of pre-programmed cycles of operation to remove moisture from the laundry items by the application of heat, typically through a heated air flow. The laundry items may be damaged by the application of excess heat during a cycle of operation if the temperature and/or moisture level of the laundry items increases above a predetermined threshold. In addition, the application of excess heat may be energy inefficient and result in an operating cycle that is longer than necessary.

SUMMARY OF THE INVENTION

A method for estimating the temperature of a laundry load in a treating chamber of a laundry dryer, with the treating chamber having an air inlet and an air outlet, comprises determining an inflow temperature value indicative of the temperature of air entering the treating chamber, determining an outflow temperature value indicative of the temperature of air exiting the treating chamber and determining a load amount value indicative of the amount of the laundry load in the treating chamber. A laundry temperature value indicative of the laundry load temperature may be determined based on the inflow temperature, the outflow temperature and the load amount value.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a schematic view of a laundry treating appliance according to an embodiment of the invention.

FIG. **2** is a front perspective view of a laundry treating appliance according to an embodiment of the invention.

FIG. **3** is a partial perspective view of the laundry treating appliance of FIG. **2** with portions of the cabinet removed for clarity according to an embodiment of the invention.

FIG. **4** is a second partial perspective view of the laundry treating appliance of FIG. **2** with portions of the cabinet removed for clarity according to an embodiment of the invention.

FIG. **5** is a schematic view of the laundry treating appliance of FIG. **2** according to an embodiment of the invention.

FIG. **6** is a schematic representation of a controller for controlling the operation of one or more components of the laundry treating appliance of FIG. **2** according to an embodiment of the invention.

FIG. **7** is a schematic representation of air flow through a laundry treating appliance according to an embodiment of the invention.

FIG. **8** is a flow chart illustrating a method for estimating the temperature of a laundry load in a laundry treating appliance according to an embodiment of the invention.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

FIG. **1** illustrates one embodiment of a laundry treating appliance **10** in the form of a clothes dryer according to the invention. While the laundry treating appliance **10** is illustrated as a clothes dryer, the laundry treating appliance **10** according to the invention may be any appliance which performs a cycle of operation on laundry, non-limiting examples of which include a horizontal or vertical axis clothes dryer; a air vented dryer; a condenser dryer; a combination washing machine and dryer; a tumbling or stationary refreshing/revitalizing machine; an extractor; a non-aqueous washing apparatus; and a revitalizing machine. The laundry treating appliance **10** described herein shares many features of a traditional automatic clothes dryer, which will not be described in detail except as necessary for a complete understanding of the invention.

The laundry treating appliance **10** may comprise a cabinet **12** having a controller **14** for controlling the operation of the laundry treating appliance **10** to complete a cycle of operation. A rotatable drum **28** may be located within the cabinet **12** defining a treating chamber **34** for receiving laundry to be treated during a cycle of operation.

Still referring to FIG. **1**, an air flow system for the clothes dryer **10** according to one embodiment of the invention will now be described. As illustrated by arrows **40**, the air flow system supplies air to the treating chamber **34** and then exhausts air from the treating chamber **34**. The supplied air may be heated or not. The air flow system may have an inflow portion **41** that may be formed in part by an inlet conduit **42**, which has one end open to the ambient air and another end fluidly coupled to an inlet channel **44**, which may be in fluid communication with the treating chamber **34** through an air inlet **45**. A heating element **46** may lie within the inlet conduit **42** and may be operably coupled to and controlled by the controller **14**. If the heating element **46** is turned on, the supplied air will be heated prior to entering the drum **28**. The inflow portion **41** may further include an inflow temperature sensor **48** to sense the temperature of the air supplied to the treating chamber **34**. The inflow temperature sensor **48** may be located anywhere in the inflow portion **41** and may be operably coupled to the controller **14**.

The air flow system may further include an outflow portion **51** that may be formed in part by an exhaust conduit **52** and exhaust channel **54**, which are fluidly coupled by a blower **56**. The blower **56** may be operably coupled to and controlled by the controller **14**. Operation of the blower **56** draws air into the treating chamber **34** as well as exhausts air from the treating chamber **34** through the air outlet **59** to the outside of the laundry treating appliance **10** through the exhaust conduit **52**. The outflow portion **51** may further include an outflow temperature sensor **58** to sense the temperature of the air exhausted from the treating chamber **34**. The outflow temperature sensor **58** may be located anywhere in the outflow portion **51** and may be operably coupled to the controller **14**.

The drum **28** may be rotated by any suitable drive mechanism, such as an indirect drive, which is illustrated as a motor **60** and a coupled belt **62**. Some non-limiting examples of indirect drive are: three-phase induction motor drives, various types of single phase induction motors such as a permanent split capacitor (PSC), a shaded pole and a split-phase motor. Alternately, the motor **60** may be a direct drive motor, as is known in the art. Some non-limiting examples of an applicable direct drive motor are: a brushless permanent magnet (BPM or BLDC) motor, an induction motor, etc. The motor **60** may be operably coupled to the controller **14** to control the rotation of the drum **28** to complete a cycle of operation. The motor **60** may be operably coupled to the controller **14** to control the rotation of the drum **28** to complete a cycle of operation.

The clothes dryer **10** may optionally have a dispensing system **64** for dispensing treatment chemistries, including without limitation water or steam, individually or collectively into the treating chamber **34**, and thus may be considered to be a dispensing dryer. The dispensing system **64** may include a dispenser **66** capable of holding and dispensing a treatment chemistry to the treating chamber **34** through a dispensing line **68**. The dispenser **66** may be positioned to direct the treatment chemistry at the inner surface of the drum **28** so that laundry may contact and absorb the chemistry, or to dispense the chemistry directly onto the laundry in the treating chamber **34**. The type of dispensing system **64** is not germane to the invention and may include additional components such as a chemistry meter to control the amount of treatment chemistry dispensed. Additionally or alternatively, the dispensing system **64** may include a steam generator for dispensing steam as a treatment chemistry into the treating chamber **34**. The dispensing system **64** may be operably coupled with the controller **14** for dispensing a treatment chemistry during a course of operation.

The clothes dryer **10** may optionally also have an imaging system **70** to image the treating chamber **34** and/or anything within the treating chamber **34**. The imaging system **70** may comprise one or more imaging devices and one or more illumination sources. Exemplary imaging devices may include any optical sensor capable of capturing still or moving images, such as a camera. One suitable type of camera is a CMOS camera. Other exemplary imaging devices include a CCD camera, a digital camera, a video camera or any other type of device capable of capturing an image. The camera may capture either or both visible and non-visible radiation. For example, the camera may capture an image using visible light. In another example, the camera may capture an image using non-visible light, such as ultraviolet light. In yet another example, the camera may be a thermal imaging device capable of detecting radiation in the infrared region of the electromagnetic spectrum. The imaging system **70** may be operably coupled with the controller **14** to capture one or more images of the treating chamber **34**.

FIG. **2** illustrates a second embodiment of the invention in the form of a clothes dryer **110** which is similar in structure to the laundry treating appliance **10**. Therefore, elements in the clothes dryer **110** similar to the laundry treating appliance **10** will be numbered with the prefix **100**. The clothes dryer **110** described herein shares many features of a traditional automatic clothes dryer which will not be described in detail except as necessary for a complete understanding of the invention.

The clothes dryer **110** may include a cabinet **112** in which is provided a controller **114** that may receive input from a user through a user interface **116** for selecting a cycle of operation and controlling the operation of the clothes dryer **110** to implement the selected cycle of operation.

The cabinet **112** may be defined by a front wall **118**, a rear wall **120**, and a pair of side walls **122** supporting a top wall **124**. A door **126** may be hingedly mounted to the front wall **118** and may be selectively moveable between opened and closed positions to close an opening in the front wall **118**, which provides access to the interior of the cabinet.

A rotatable drum **128** may be disposed within the interior of the cabinet **112** between opposing stationary rear and front bulkheads **130** and **132**, which collectively define a treating chamber **134**, for treating laundry, having an open face that may be selectively closed by the door **126**. Non-limiting examples of laundry include, but are not limited to, a hat, a scarf, a glove, a sweater, a blouse, a shirt, a pair of shorts, a dress, a sock, a pair of pants, a shoe, an undergarment, and a jacket. Furthermore, textile fabrics in other products, such as draperies, sheets, towels, pillows, and stuffed fabric articles (e.g., toys), may be dried in the clothes dryer **110**.

The drum **128** may include at least one lifter **136**. In most dryers, there are multiple lifters. The lifters **136** may be located along the inner surface of the drum **128** defining an interior circumference of the drum **128**. The lifters **136** may facilitate movement of the laundry within the drum **128** as the drum **128** rotates.

Referring now to FIG. **3**, an air flow system for the clothes dryer **110** according to one embodiment of the invention will now be described. The air flow system supplies air to the treating chamber **134** and then exhausts air from the treating chamber **134**. The supplied air may be heated or not. The air flow system may have an inflow portion **141** that may be formed in part by an inlet conduit **142**, which has one end open to the ambient air and another end fluidly coupled to an inlet grill **144**, which may be in fluid communication with the treating chamber **134**. A heating element **146** may lie within the inlet conduit **142** and may be operably coupled to and controlled by the controller **114**. If the heating element **146** is turned on, the supplied air will be heated prior to entering the drum **128**. The inflow portion **141** may further include an inflow temperature sensor **148** to sense the temperature of the air supplied to the treating chamber **134**. The inflow temperature sensor **148** may be located anywhere in the inflow portion **141** to sense the temperature of the air flow before it enters the treating chamber **134** and may be operably coupled to the controller **114**. The temperature sensor **148** may be any suitable type of temperature sensor such as a thermistor, thermocouple or RTD, for example.

Referring to FIG. **4**, the air flow system may further include an outflow portion **151** that may be formed in part by an exhaust conduit **152** and lint trap **154**, which are fluidly coupled by a blower **156**. The blower **156** may be operably coupled to and controlled by the controller **114**. Operation of the blower **156** draws air into the treating chamber **134** as well as exhausts air from the treating chamber **134** through the exhaust conduit **152**. The exhaust conduit **152** may be fluidly coupled with a household exhaust duct **157** for exhausting the air from the treating chamber **134** to the outside. The outflow portion **151** may further include an outflow temperature sensor **158** to sense the temperature of the air exhausted from the treating chamber **134**. The outflow temperature sensor **158** may be located anywhere in the outflow portion **151** to sense the temperature of the air flow after it has been exhausted from the treating chamber **134** and may be operably coupled to the controller **114**. The temperature sensor **158** may be any suitable type of temperature sensor such as a thermistor, thermocouple or RTD, for example.

Referring now to FIG. **5**, as is typical in a clothes dryer, the drum **128** may be rotated by a suitable drive mechanism, such as an indirect drive, which is illustrated as a motor **160** and a coupled belt **162**. Some non-limiting examples of indirect drive are: three-phase induction motor drives, various types of single phase induction motors such as a permanent split capacitor (PSC), a shaded pole and a split-phase motor. Alternately, the motor **160** may be a direct drive motor, as is known in the art. Some non-limiting examples of an applicable direct drive motor are: a brushless permanent magnet (BPM or BLDC) motor, an induction motor, etc. The motor **160** may be operably coupled to the controller **114** to control the rotation of the drum **128** to complete a cycle of operation.

Still referring to FIG. **5**, the clothes dryer **10** may optionally have a dispensing system **164** for dispensing treatment chemistries, including without limitation water or steam, into the treating chamber **134**, and thus may be considered to be a dispensing dryer. The dispensing system **164** may include a dispenser **166** capable of holding and dispensing a treatment chemistry into the treating chamber **134**. The dispenser **166** may be fluidly coupled with a nozzle **165** in fluid communication with the treating chamber **134** through a dispensing line **168**. The nozzle **165** may be positioned to direct the treatment chemistry at the inner surface of the drum **128** so that laundry may contact and absorb the chemistry, or to dispense the chemistry directly onto the laundry in the treating chamber **134**. The type of dispenser system **164** is not germane to the invention and may include additional components such as a chemistry meter to control the amount of treatment chemistry dispensed. Additionally or alternatively, the dispensing system **164** may include a steam generator for dispensing steam as a treatment chemistry into the treating chamber **134**. The treatment chemistry may be in a form of gas, liquid, solid or any combination thereof and may have any chemical composition enabling improved wrinkle, odor, softness, whitening, brightening, addition of fragrance, or any other desired treatment of the laundry.

The clothes dryer **10** may also have an imaging system **170** comprising one or more imaging devices **172** and one or more illumination sources **174** to image the treating chamber **134** and/or anything within the treating chamber **134**. The imaging system **170** may be similar to that which is described in Applicant's co-pending application bearing Applicant's reference number US20080156, titled "Laundry Treating Appliance with Load Surface Area Detection." Exemplary imaging devices **172** may include any optical sensor capable of capturing still or moving images, such as a camera. One suitable type of camera is a CMOS camera. Other exemplary imaging devices include a CCD camera, a digital camera, a video camera or any other type of device capable of capturing an image. The camera may capture either or both visible and non-visible radiation. For example, the camera may capture an image using visible light. In another example, the camera may capture an image using non-visible light, such as ultraviolet light. In yet another example, the camera may be a thermal imaging device capable of detecting radiation in the infrared region of the electromagnetic spectrum. The imaging device **172** may be located on either of the rear or front bulkhead **130**, **132** or in the door **126**. It may be readily understood that the location of the imaging device **172** may be in numerous other locations depending on the particular structure of the dryer and the desired position for obtaining an image. There may also be multiple imaging devices, which may image the same or different areas of the treating chamber **134**.

The type of illumination source **174** may vary. In one configuration, the illumination source **174** may be a typical incandescent dryer light which is commonly used to illuminate the treating chamber **134**. Alternatively, one or more LED lights may be used in place of an incandescent bulb. The illumination source **174** may also be located behind the rear bulkhead **130** of the drum **128** such that the light shines through the holes of the air inlet grill **144**. It is also within the scope of the invention for the clothes dryer **110** to have more than one illumination source **174**. For example, an array of LED lights may be placed at multiple positions in either bulkhead **130**, **132**.

As illustrated in FIG. **6**, the controller **114** may be provided with a memory **180** and a central processing unit (CPU) **182**. It is contemplated that the controller **114** is a microprocessor-based controller that implements control software stored in the memory **180** which may be internal to or in communication with the microprocessor. The memory **180** may comprise one or more software applications, and send/receive one or more electrical signals to/from each of the various working components to affect the control software. Examples of possible controllers are: proportional control (P), proportional integral control (PI), and proportional derivative control (PD), or a combination thereof, a proportional integral derivative control (PID control), which may be used to control the various components of the clothes dryer **110**.

The controller **114** may be communicably and/or operably coupled with one or more components of the clothes dryer **110** for communicating with and controlling the operation of the component to complete a cycle of operation. For example, the controller **114** may be coupled with the heating element **146**, the inflow temperature sensor **148**, the outflow temperature **158** and the blower **156** for controlling the temperature and flow rate of air through the treating chamber **134**; the motor **160** for controlling the direction and speed of rotation of the drum **128**; the imaging system **170** for capturing one or more images of the treating chamber **134**; and the dispensing system **164** for dispensing a treatment chemistry during a cycle of operation. The controller **114** may also be coupled with the user interface **116** for receiving user selected inputs and communicating information to the user.

The controller **114** may also receive input from various sensors **184**, which are known in the art and not shown for simplicity. Non-limiting examples of sensors **184** that may be communicably coupled with the controller **114** include: a moisture sensor, an air flow rate sensor, a weight sensor, and a motor torque sensor.

The previously described laundry treating appliances **10** and **110** may be used to implement one or more embodiments of a method of the invention. Several embodiments of the method will now be described in terms of the operation of the clothes dryer **110**. While the methods are described with respect to the clothes dryer **110**, the methods may also be used with the laundry treating appliance **10** of the first embodiment of the invention. The embodiments of the method function to automatically determine the temperature of the laundry load within the treating chamber **134**. The determined temperature of the laundry load may be used by the controller **114** to control the operation of the clothes dryer **110**.

Controlling the operation of the clothes dryer **110** based on the determined temperature of the laundry load may include setting at least one parameter of a cycle of operation including a rotational speed of the drum **128**, a direction of rotation of the drum **128**, a temperature in the treating chamber **134**, an air flow through the treating chamber **134**, a type of treatment chemistry, an amount of treatment chemistry, a start or end of cycle condition and a start or end cycle step condition.

Setting a start or end of cycle condition may include determining when to start or end a cycle of operation. This may include signaling the controller **114** to immediately start or end a cycle of operation or setting a time at which to start or end a cycle of operation.

Setting a start or end of cycle step condition may include determining when to start a step or phase within a given operating cycle or when to end a step within a given operating cycle. This may include signaling the controller **114** to immediately transition from one cycle step to another or setting a time at which to transition from one step to another within a given operating cycle. Examples of cycle steps include rotation with heated air, rotation without heated air, treatment dispensing, a wrinkle guard step and cool down step.

Determining the temperature of the laundry load according to the present invention may be used to enable a variety of adaptive cycles having adaptive drying settings (for example, drying temperature), a better estimated end of cycle, improved energy savings and improved delivery of laundry care with less damage to the laundry fabric.

The temperature of the laundry load may be estimated by considering the partition of the air flow through the air flow system of the clothes dryer **110** into two sub-flows of air as illustrated by a schematic representation **200** of the air flow system in FIG. **7**. The schematic representation **200** is a conceptual illustration of the air flow system for the purposes of illustration only and is not meant to limit the invention in any manner. The inflow air **202** may enter the treating chamber **134** and separate into two sub-flows of air, an unperturbed air flow **204** and a perturbed air flow **206**. The undisturbed or unperturbed air flow **204** is the portion of the inflow air **202** that flows through the treating chamber **134** with no interaction with the laundry load. The perturbed air flow **206** is the portion of the inflow air **202** that interacts with the laundry load in the treating chamber **134**. The two sub-flows, the unperturbed air **204** and the perturbed air **206** mix as they are exhausted from the treating chamber **134** to form the outflow air **208**.

For convenience of illustration, the perturbed and unperturbed air flows **206**, **204** are illustrated with single discrete arrows. In reality, because the laundry is moving within the treatment chamber, there will be many different perturbed and unperturbed air flows, each of which could be illustrated with their own arrows. The arrows **206**, **204** are meant to conceptually simplify the illustration and explanation and are not meant to indicate the exact physical location and volume of each of the perturbed and unperturbed air flows.

The unperturbed air **204** does not interact with the laundry load and therefore the thermodynamic state of the unperturbed air **204** does not change as it flows through the treating chamber **134**. The perturbed air **206** interacts with the fabric of the laundry load, exchanging mass and energy, and thus its thermodynamic state changes. The partitioning of the inflow air **202** into the unperturbed air flow **204** and the perturbed air flow **206** is a function of the amount of the laundry load. The load amount may be a quantitative amount, non-limiting examples of which include the weight, mass, volume, density and area of the laundry load.

For example, as the mass of the load increases, the proportion of the perturbed air **206** in the outflow air **208** increases as the proportion of the unperturbed air **204** decreases. In another example, the surface area of the load may be used to determine the partition of the inflow air **202**. Laundry loads having a larger surface area have more surface area to interact with the inflow air **202** than laundry loads having a smaller surface area. In yet another example, the partitioning of the inflow air **202** may be determined based on the volume of the chamber occupied by the laundry load. Laundry loads having a larger volume may interact more with the inflow air **202** than laundry loads having a smaller volume because there is less space for the inflow air **202** to pass unperturbed through the treating chamber **134** than when a small load is present in the treating chamber **134**.

Because the thermodynamic state of the unperturbed air **204** does not change as it passes through the treating chamber **134**, the temperature of the inflow air **202** is indicative of the temperature of the unperturbed air **204**. The perturbed air **206** interacts with the laundry load and therefore the thermodynamic state of the perturbed air **206** is indicative of the temperature of the laundry load. As a result of the mixing of the unperturbed air **204** and the perturbed air **206** as the air is exhausted from the treating chamber **134**, the temperature of the outflow air **208** is a function of the temperature of the unperturbed air **204**, the perturbed air **206** and the amount of the laundry load, which determines the partitioning of the inflow air **202**. Because the temperature of the perturbed air **206** is representative of the temperature of the laundry load, the temperature of the laundry load may be estimated as illustrated in equation (1).

$$T_{load}=f(T_{inflow\ air}, T_{outflow\ air}, \text{Load Amount}) \quad (1)$$

T_{load} represents the temperature of the laundry load and Load Amount represents the amount of the load. $T_{inflow\ air}$ is representative of the temperature of the inflow air **202** being supplied to the treating chamber **134** and may be determined using the inflow temperature sensor **148**. $T_{outflow\ air}$ represents the temperature of the outflow air **208** being exhausted from the treating chamber **134** and may be determined using the outflow temperature sensor **158**.

One example of an algorithm that may be used to determine the temperature of the load T_{load} may be based on considering the moist air enthalpy and the dry air mass flow rate of the inflow air **202**, the perturbed air **206** and the outflow air **208** using a simple model of the actual process. The dry air mass flow rate of the inflow air **202** may be assumed to be equal to the sum of the unperturbed air **204** and the perturbed air **206** dry air mass flow rates. The moist air enthalpy may be represented by equations (2)-(4) where h_{inflow}, $h_{perturbed}$ and $h_{outflow}$ represents the moist air enthalpy of the inflow air **202**, the perturbed air **206** and the outflow air **208**, respectively. X_{inflow}, $X_{perturbed}$ and $X_{outflow}$ represent the humidity ratio of the inflow air **202**, the perturbed air **206** and the outflow air **208**, respectively. k_1, k_2 and k_3 are thermodynamic constants.

$$h_{inflow}=k_3 T_{inflow}+(k_1+k_2*T_{inflow})*X_{inflow} \quad (2)$$

$$h_{perturbed}=k_3*T_{perturbed}+(k_1+k_2*T_{perturbed})*X_{perturbed} \quad (3)$$

$$h_{outflow}=k_3*T_{outflow}+(k_1+k_2*T_{outflow})*X_{outflow} \quad (4)$$

The dry air mass flow rate may be represented by the following equation (5) where $\dot{m}dry_{\_air}$ represents the dry air mass flow rate of the outflow air **208**, $\dot{m}_{dry\_air}*\phi$ represents the dry air mass flow rate of the perturbed air **206** and $\dot{m}_{dry\_air}*(1-\phi)$ represents the dry air mass flow rate of the inflow air **202** passing unperturbed through the treating chamber **134** and where ϕ equals the Load Amount multiplied by a first calibration constant plus a second calibration constant.

$$\dot{m}_{dry\_air}*X_{outflow}=\dot{m}_{dry\_air})*(1-\phi)*X_{inflow}+\dot{m}_{dry\_air}*\phi*X_{perturbed} \quad (5)$$

It may be assumed with inconsequential error that the evaporation process at each temporal instant is at constant enthalpy so that $h_{inflow}=h_{perturbed}=h_{outflow}$. As described above, the perturbed air **206** interacts with the laundry load and therefore the temperature of the perturbed air **206** is indicative of the temperature of the laundry load. Therefore, it may be assumed with inconsequential error that $T_{perturbed}=T_{load}$. Equations (2)-(5) may then be solved to provide the following algorithm for determining the temperature of the laundry load (6):

$$T_{load}=(T_{inflow}*\phi*k_1+T_{inflow}*T_{outflow}*\phi*k_2-k_1*T_{inflow}+k_1*T_{outflow})/(*k_1+\phi*k_2*T_{outflow}+k_2*T_{inflow}-k_2*T_{outflow}) \quad (6)$$

The moist air enthalpy h and the humidity ratio X are parameters that are not easily directly measurable. By making the assumption that $k_{inflow}=h_{perturbed}=h_{outflow}$, equations 2-5 may be solved to determine $T_{perturbed}$ using parameters that may be directly measured, such as the inflow and outflow temperatures, T_{inflow} and $T_{outflow}$. Based on the assumption that $T_{perturbed}=T_{load}$, equation (6) may then be solved for T_{load} as illustrated above.

Referring to FIG. **8**, a flow chart of one method **300** of estimating the temperature of the laundry load is shown in accordance with the present invention. The laundry load temperature estimation method **300** may be executed by the controller **114** during a drying or treatment cycle of the clothes dryer **110**. The sequence of steps depicted is for illustrative purposes only, and is not meant to limit the fabric temperature estimation method **300** in any way as it is understood that the steps may proceed in a different logical order or additional or intervening steps may be included without detracting from the invention. While the method **300** is described in the context of the clothes dryer **110**, it is understood that method **300** may also be used with the laundry treating appliance **10**.

The method **300** starts with assuming that the user has loaded the clothes dryer **110** with one or more articles to form the laundry load and closed the door **126**. The method **300** may be initiated at the start of a user selected operating cycle or at some predetermined time after the start of the user selected operating cycle at **302**.

At **304**, the amount of the laundry load may be determined. The determination of the load at **304** may be part of the treatment cycle or it may be a separate cycle completed prior to the start of the treatment cycle. Determining the amount of the laundry load may include determining the mass, weight, volume, packing density and area of the laundry load and may be done in any suitable manner. For example, the load amount determination may be provided by a user via user interface **116** or via data indicative of the load amount received from one or more sensors related to the motor **160**, the drum **128** or any other components of the clothes dryer **110**. In another example, the drum **128** may be rotated to acquire one or more motor characteristics which may be used to derive the amount of the load. The characteristic of the motor **160** may be any data related to the operation of the motor **160**, such as motor torque, motor speed, motor current and motor voltage.

The load amount may also be determined based on the readings from one or more temperature sensors. One method for determining the load amount is set forth in Applicant's co-pending application bearing Applicant's reference number US20090295, titled "Method for Determining Load Size in a Clothes Dryer Using an Infrared Sensor." An infrared temperature sensor may be used to obtain multiple temperature readings inside a treating chamber of a clothes dryer. The variation in the temperature readings may be used to determine the load amount.

In another example, the amount of the load may be determined based on the surface area of the load. The surface area of the load may be determined using any suitable method. One method for determining the surface area of the load is set forth in Applicant's co-pending application bearing Applicant's reference number US20080156, titled "Laundry Treating Appliance with Load Surface Area Detection." According to the load surface area method of US20080156, an imaging device may be used to capture one or more images of a treating chamber. The captured images may be sent to a controller for analysis using software associated with the controller to determine the surface area of the load within the treating chamber. According to the current method, the determined surface area may then be used to determine the partitioning of the inflow air as described above which may then be used to estimate the temperature of the fabric load at **310**.

In another example, the amount of the load may be determined based on the packing density of the load. The packing density of the load may be determined using any suitable method. One method for determining the packing density of the load is set forth in Applicant's co-pending application bearing Applicant's reference number US20080165, titled "Laundry Treating Appliance with Tumble Pattern Control." The method according US20080165 converts the motor torque signal while the drum is rotating from the time domain to the frequency domain in order to estimate the packing density. The packing density may be characterized in terms of the free space within the treating chamber not occupied by the load, the ratio of the volume of the laundry load to the total volume of the treating chamber or the ratio of the free volume of the treating chamber to the total volume of the treating chamber. According to the current method, the determined volume of either the laundry load or the free volume of the treating chamber may then be used to determine the partitioning of the inflow air as described above which may then be used to estimate the temperature of the fabric load at **310**.

At **306** and **308** the temperature of the inflow air and outflow air may be measured by the inflow temperature sensor **148** and the outflow temperature sensor **158**, respectively, and sent to the controller **114** for analysis using software that is stored in the memory **180** of the controller **114**.

At **310** the load amount determined at **304** and the inflow and outflow air temperatures measured at **306** and **308**, respectively, may be used by software stored in the memory **180** of the controller **114** to determine the temperature of the laundry load. For example, the load amount and inflow and outflow air temperatures may be used to solve the algorithm of equation (6) to determine the temperature of the load.

At **312** the cycle parameters may be adjusted based on the laundry load temperature determined at **310**. The determined fabric temperature may be used by the controller **114** to set one or more parameters of a cycle of operation including a rotational speed of the drum **128**, a direction of rotation of the drum **128**, a temperature in the treating chamber **134**, an air flow through the treating chamber **134**, a type of treatment chemistry, an amount of treatment chemistry, a start or end of cycle condition and a start or end cycle step condition.

The method **300** may be completed once during the course of a cycle of operation. Alternatively, elements **304**-**312** or **306**-**312** of the method **300** may be repeated a plurality of times during a cycle of operation to determine the temperature of the laundry load and adjust the cycle parameters at multiple times throughout the cycle of operation.

The method **300** provides a real-time estimate of the temperature of the laundry load and may be used to increase energy and time efficiency by maximizing the removal of water during the drying process while minimizing the energy provided to the system. By monitoring the temperature of the laundry load during the course of an operating cycle, one or more cycle parameters may be adjusted to achieve a desired dryness level without over drying or over heating the laundry load. Avoiding over drying and over heating of the laundry load saves time and energy and also minimizes damage to the laundry load. In addition, by taking into account the amount of the load, the estimation of the temperature of the laundry load may be more accurate over a larger range of load amounts. This may be particularly advantageous for small laundry loads which may quickly become over dried and/or over heated.

While the invention has been specifically described in connection with certain specific embodiments thereof, it is to be understood that this is by way of illustration and not of limitation. Reasonable variation and modification are possible within the scope of the forgoing disclosure and drawings without departing from the spirit of the invention which is defined in the appended claims. For example, the sequence of steps depicted in each method described herein is for illustrative purposes only, and is not meant to limit the disclosed methods in any way as it is understood that the steps may proceed in a different logical order or additional or intervening steps may be included without detracting from the invention.

What is claimed is:

1. A laundry dryer comprising:

a rotatable drum defining a treating chamber for receiving a laundry load for drying and having an air inlet and an air outlet;

an air flow system having an inflow portion fluidly coupled with the treating chamber at the air inlet to provide inflow air to the treating chamber and an outflow portion fluidly coupled with the treating chamber through the air outlet to exhaust outflow air from the treating chamber;

a heating system thermally coupled with the inflow portion and operable to heat the inflow air;

an inflow temperature sensor operable to provide an inflow temperature output indicative of the temperature of the inflow air;

an outflow temperature sensor operable to provide an outflow temperature output indicative of the temperature of the outflow air;

a load sensor operable to provide a load size output indicative of the size of the laundry load in the treating chamber; and

a controller coupled with the inflow temperature sensor, the outflow temperature sensor, and the load sensor, the controller having a laundry temperature estimation algorithm and operable to receive the inflow temperature output, the outflow temperature output, and the load size output, respectively, wherein the controller applies the inflow temperature output, outflow temperature output, and the load size output as input parameters to the laundry temperature estimation algorithm and provides a laundry temperature output indicative of the temperature of the laundry load.

2. The laundry dryer of claim **1** wherein the inflow portion comprises an inlet conduit coupled with the air inlet and the outflow portion comprises an outlet conduit coupled with the air outlet, and wherein the inflow temperature sensor is located in one of the inlet conduit and the air inlet, and the outflow temperature sensor is located in one of the outlet conduit and the air outlet.

3. The laundry dryer of claim **1** wherein the laundry temperature estimation algorithm applies the inflow temperature output, outflow temperature output, and load size output to determine an air flow temperature of an air flow of perturbed air passing through the treating chamber and contacting the laundry load, which is used to determine the temperature of the laundry load.

4. The laundry dryer of claim **3** wherein the laundry temperature estimation algorithm relates the determined air flow temperature of the perturbed air with an actual temperature of the laundry load to determine the temperature of the laundry load.

5. The laundry dryer of claim **1** wherein the controller uses the laundry temperature output to control at least one of a drying cycle and a phase of a drying cycle.

6. The laundry dryer of claim **5** wherein the controller uses the laundry temperature output to terminate at least one of the at least one drying cycle and drying phase.

7. The laundry dryer of claim **1** wherein the controller uses the laundry temperature output to control an amount of heat generated by the heating system.

8. The laundry dryer of claim **1** wherein the controller uses the laundry temperature output to terminate a drying phase and initiate a cool down phase.

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